controls the 4–20 mA current energizing the radar level gauge to have an analog value representing the level. Microcontroller **208** utilizes memory **214** and also coupled to a digital I/O circuit **216** which provides two way digital communication over the 4–20 mA loop. The digital communication can be in the HART or Fieldbus format, or other known digital formats. Blocking capacitors **218** are interposed between digital I/O circuit **216** and the 4–20 mA loop to block the analog current from flowing through the digital I/O circuit. The radar gauge of FIG. 7 is energized solely by a 4–20 mA analog current **202** and includes a voltage regulator **204** energized by the 4–20 mA analog current.

In the circuits of FIGS. 5–7, frequency stabilization is used in sensing fluid level in a tank. First and second clock frequencies are generated, separated from each other by a first frequency separation controlled by a control input. First and second clock frequencies are divided to generate the transmit and sample frequencies separated from each other by a second frequency separation. Evaluation outputs are generated as functions of the first and second frequency separations. A control output is generated and fed back to the control input that stabilizes the first frequency separation as a function of the evaluation outputs. A level output is generated as a function of the stabilized first frequency separation.

A program to perform these processes can be loaded into controller **154** from a computer-readable medium having stored thereon a plurality of sequences of instructions for execution by a processor in a radar gauge adapted to sense fluid level in a tank.

In FIG. **8**, a circuit diagram of a divider circuit and a separation sensing circuit such as circuit **150** is shown. A system clock frequency is received at **250**, and a VCO frequency is received at **252**. A first divide by two circuit **254** divides the system clock frequency and generates a transmit clock frequency **126**. A second divide by two circuit **256** receives the VCO frequency and generates a sample clock frequency **128**. A first frequency difference circuit **258** receives both the system clock frequency and the VCO frequency and generates a first frequency difference output at **260**. A second frequency difference circuit **262** receives the transmit clock frequency and the sample clock frequency and generates a second frequency difference output at **264**. A polarity sensing circuit **266** senses the polarity of the sample clock relative to the second frequency difference output and generates a polarity, or sign, output at **268**. Each of the functions in FIG. **8** can be performed using a low cost type 7474 clocked D flip flop wired as shown in FIG. **8**.

The sample polarity detector is connected as a latch that stores the polarity of the sample clock after the leading edge of the transmit clock toggles the Q/ output of the second difference frequency detector. The output of the transmit sample polarity detector is coupled to the microprocessor to indicates whether the sample clock has a lower or higher frequency that the transmit clock. The polarity detector resolves any ambiguity in the absolute value of the frequency difference.

The radar level gauge with stabilization has the advantage of low cost and low phase jitter, while improving overall performance.

The stabilization allows a low cost pulsed microwave radar measurement to be made with improved performance. The method involves measuring and correcting for the difference between the two critical clock frequencies required in this system, as opposed to trying to precisely generate or control these frequencies.

A timer in the microprocessor counts or times the outputs of the first and second difference frequency detectors. Based on these counts or times, the microprocessor calculates real time data representing the absolute value of the frequency difference between the transmit frequency and the sample frequency. The microprocessor then executes an algorithm that adjusts the control voltage provided to the VCO to maintain the difference frequency in a desired range. The control algorithm in the microprocessor is adjusted so that it does not tightly control the frequency difference, but maintains only limited control within the desired range. The use of limited control rather than tight control of the frequency difference allows low power, low resolution components to be used in the frequency control. Oscillator drift is too fast for the low power, low resolution circuitry to control it, making frequency difference counts somewhat different during each measurement.

The timer is also used to precisely count the somewhat varying difference frequency during the exact time that the distance is being measured. The microprocessor then adjusts the distance calculation based on the actual count of the difference frequency. The timer can be a hardware timer, software implemented in a microprocessor, or a combination of both. In the microprocessor's algorithm or equation for calculating distance, the frequency difference term ΔF is a real time variable measured by the timer rather than a constant term or a term adjusted only infrequently for compensation.

The combination of limited control of the frequency difference with a precise count of the frequency difference enables the radar gauge to operate with lower noise due to phase jitter in combination with higher accuracy due to precise correction of distance measurement for variations in frequency during the measuring interval and the overall performance of the radar gauge is improved. High phase jitter on the sample clock leads to an unstable equivalent time measurement and instability at level output 132.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the scope of the invention.

What is claimed is:

1. A radar gauge adapted to sense fluid level in a tank, comprising:

a radar gauge circuit adapted to receive a transmit frequency and a sample frequency controlling radar transmission and level sampling respectively, the radar gauge circuit generating a level output;

a clock source generating first and second clock frequencies and having a control input setting a first frequency separation between the first and second clock frequencies;

a separation sensing circuit coupled to the clock source and generating an evaluation output as a function of the first frequency separation;

a controller receiving the evaluation output, the controller having a timer that measures the frequency separation and a control output feeding back to the control input that stabilizes the first separation as a function of timing the evaluation outputs, the controller further having a correction circuit that corrects the level output as a function of the first frequency separation;

a divider circuit dividing the first and second clock frequencies and generating the transmit and the sample frequencies wherein the transmit and sample frequencies are separated from each other by a second frequency separation; ~~and~~

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the separation sensing circuit further coupling to the divider circuit and generating a second evaluation output coupling to the controller as a function of the second frequency separation.

2. The radar gauge of claim 1 wherein the separation sensing circuit further comprises:

a circuit sensing a polarity of the sample clock and generating a further evaluation output representative of the polarity.

3. The radar gauge of claim 1 wherein the clock source comprises a voltage controlled oscillator controlled by the control output and generating the second clock frequency.

4. The radar gauge of claim 3 wherein the controller comprises a digital-to-analog converter generating the control output.

5. The radar gauge of claim 1 wherein the controller includes a timer measuring time intervals of an evaluation output.

6. The radar gauge of claim 5 wherein the level output includes a current calculated distance that is a function of a current timer measurement.

7. The radar gauge of claim 1 wherein the controller includes a timer performing a timer measurement of a count an evaluation output during a time interval.

8. The radar gauge of claim 7 wherein the level output includes a current calculated distance that is a function of a current timer measurement.

9. The radar gauge of claim 1 wherein the radar gauge circuit includes a transmit pulse generator and a sample pulse generator controlled respectively by the transmit clock and the sample clock.

10. The radar gauge of claim 1 wherein the radar gauge is energized solely by a 4–20 mA analog current and includes a voltage regulator energized by the 4–20 mA analog current.

11. A method of stabilizing clock generation in a radar gauge adapted to sense fluid level in a tank, comprising:

generating first and second clock frequencies separated from each other by a first frequency separation controlled by a control input;

generating a first evaluation output as a function of the first frequency separation;

generating a control output feeding back to the control input that stabilizes the first separation as a function of the evaluation output;

generating a level output as a function of the stabilized first frequency separation, the level output corrected as a function of the first frequency separation;

dividing the first and second clock frequencies to generate the transmit and sample frequencies separated from each other by a second frequency separation;

generating a second evaluation output as a function of the second frequency separation;

generating the control output as a further function of the second evaluation output; and

correcting the level output as a function of the second evaluation output.

12. The method of claim 11 further comprising:

sensing a polarity of the sample clock and generating a further evaluation output representative of the polarity.

13. The method of claim 11 further comprising:

generating the second clock frequency in a voltage controlled oscillator wherein an oscillator control voltage is controlled by the control output.

14. The method of claim 13 further comprising:

generating the oscillator control voltage in a digital-to-analog converter.

15. A radar gauge adapted to sense fluid level in a tank, comprising:

means for receiving a transmit frequency and a sample frequency controlling radar transmission and level sampling respectively, and for generating a level output;

means for generating first and second clock frequencies separated from each other by a first frequency separation, the clock source having a control input setting the first separation;

means for dividing the first and second clock frequencies and for generating the transmit and sample clock frequencies separated from each other by a second frequency separation;

means for sensing the first and second frequency separations and generating evaluation outputs as functions of the first and second frequency separations; and

means for controlling a control output feeding back to the control input, stabilizing the first separation as a function of the evaluation outputs.

16. The radar gauge of claim 15, further comprising:

means for sensing a polarity of the sample clock and generating a further evaluation output representative of the polarity.

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